

UNIVERSITY OF PENNSYLVANIA

THE EFFECT OF BRIGHTNESS IN
THE RANGE OF ATTENTION
EXPERIMENT

STANLEY F. COOPER

A THESIS

IN PSYCHOLOGY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

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THE EFFECT OF BRIGHTNESS IN THE RANGE OF ATTENTION EXPERIMENT

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INTRODUCTION

From the point of view of structural psychology, sensation is to be defined in terms of its attributes. The attributes common to all sensations are quality, intensity, duration and clearness,¹ that these have independent status, is established by both logical and introspective analysis. The only possible confusion—that between intensity and clearness—is conclusively resolved by appeal to the familiar fact that attention to an intensively weak component of a sensation-complex brings it out clear and vivid in consciousness, without appreciably altering its relative intensity. So much is clear.

Whether independent status implies independent variability is a controversial question.² The ultimate answer to this problem can be arrived at only by appeal to actual experiment, supplemented by introspective report.

The object of this experiment is to arrive at a preliminary determination of the influence upon clearness produced by variation of stimulus-intensity. It were indeed a fond hope to expect anything more than a tentative and provisional answer to our question, based, as the results necessarily are, upon the highly specialized conditions of our experimental setting. Nevertheless, it is the writer's belief that conclusions, validly drawn from careful and accurate experimental results, cannot but throw some light upon this moot question.

Many ambiguous results have been obtained from experiments to determine whether or not intensity is increased by attention. With this phase we are not directly concerned in this study. Our principal concern is with a comparison of the clearness of perception resulting from objectively varied intensities of stimulus, and we have adopted, as our means of approach, the familiar problem of statistically calculated limens for visual apprehension of dots—the old so-called range of attention.

The writer is well aware of the possibility that the question may be raised as to the validity of his basic assumption, viz., that the limen values for apprehension of different stimulus-intensities afford a true measure-

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¹Külpe, Dunlap, Warren, and others omit 'clearness' from the list of attributes of sensation and include 'extensity.' Külpe does not distinguish clearness from intensity; he says, "intensity itself is the property of sensation which enables us to compare it with others in respect of vividness." (*Outlines of Psychology*, 1895, 30.)

²Cf. E. B. Titchener, *Lectures on the Elementary Psychology of Feeling and Attention*, 1908, 9 f.

ment of clearness of apprehension. The distinction and independent variability between attributive clearness and cognitive clearness, pointed out by Dallenbach,³ are confirmed in this study. Despite this complication, however, we are convinced that our assumption is justified not alone by the insurmountable practical difficulty of maintaining constancy of attitude,⁴ but also by the results themselves.

In regard to the problem of the relationship between intensity and clearness, Pillsbury states: "Whether the change in clearness is identical with, or dependent upon, change in intensity is as yet open to controversy."⁵

Titchener asks, "Is clearness ever independent of intensity?" and replies, "On the whole . . . the trend of psychological belief just now seems to favor an interdependence of the two attributes."⁶

The phenomenon of consciousness, in the large, has one fundamental characteristic: consciousness of something, whether it be sensation, image, feeling, idea, or perception. That is, there are always two levels of clearness to every conscious experience—a something which stands out and a background from which it stands out. This is the basis of the two-level concept of consciousness. The processes which stand out as relatively more vivid and distinct are called the focus, while the surrounding mass of unclear or obscure processes is termed the margin, fringe or background of consciousness. Whether more than one level of clearness exists in the background does not interest us here; but the possible existence of more than one clearness-level within the focal area is inextricably bound up with studies of the range of apprehension.

In the more recent tachistoscopic investigations of the so-called range of attention, just such distinction has been made between relative levels of clearness within the 'upper-level' or focal area of consciousness.

Fernberger⁷ came to the same conclusion that had been reached earlier by both Whipple⁸ and Dallenbach,⁹ viz. that 'range of attention,' as applied in the older writings, was a misnomer and rightly should be called 'range of apprehension.' This conclusion was based on the observed fact that more than one degree of clearness was discriminated by Os within the focal consciousness.

From the structuralist point of view, there is general agreement that the term 'attention' is practically synonymous with maximal clearness,¹⁰ the term 'apprehension'¹¹ is applied to several degrees of clearness found within the focal area, distinct from the definitely and sharply demarcated obscurity of the margin or background of consciousness.

³K. M. Dallenbach, *Attributive vs. cognitive clearness*, *J. Exper. Psychol.*, 3, 1920, 229. N. F. Gill and K. M. Dallenbach, *A preliminary study of the range of attention*, this JOURNAL, 37, 1926, 248.

⁴E. S. Rudisill, *Constancy of attitude in weight perception*, this JOURNAL, 36, 1925, 562-587.

⁵W. B. Pillsbury, *Attention*, 1908.

⁶E. B. Titchener, *A Text-Book of Psychology*, 1909, 212.

⁷S. W. Fernberger, *A preliminary study of the range of visual apprehension*, this JOURNAL, 32, 1921, 121-133.

⁸G. M. Whipple, *A Manual of Physical and Mental Tests*, I, 1924, 278.

⁹K. M. Dallenbach, *The effect of practice upon visual apprehension in school children*, *J. Educ. Psychol.*, 5, 1914, 321-334, 387-404; *The effect of practice upon visual apprehension in the feeble-minded*, *ibid.*, 10, 1919, 61-82; especially, *Attributive vs. cognitive clearness*, *J. Exper. Psychol.*, 3, 1920, 228 f.

¹⁰Titchener (*Text-Book of Psychology*, 267) states, "in the last resort, and in its simplest terms, attention is identical with sensory clearness." Breese (*Psychology*, 1917, 59) states, "Attention is clear and central consciousness." Pillsbury (*Attention*, 1908, 11) states, "Attention is fundamentally a change in clearness of some one phase or aspect of a mental process." Hunter (*General Psychology*, 1919, 114) says, "Attention is the clearness into and out of which objects move."

¹¹Dallenbach, *op. cit.*; Fernberger, *op. cit.*; Whipple, *op. cit.*; but see Dallenbach, Dr. Oberly on 'The range for visual attention, cognition and apprehension,' this JOURNAL, 36, 1925, 154-156.

Oberly,¹² starting with this distinction, added a third conscious pattern, which received introspective justification. The first process, which he designated as *Immediate*, was introspectively characterized by immediacy of apprehension, coupled with equal and maximal clearness of all elements; the second process, which he called *Grouped*, was similarly characterized by immediacy, but coupled with more than one level of clearness; the third process, which he called *Counted*, was marked by a temporal succession, due to a mediating process of re-imaging, coupled with more than one level of clearness. To these three conscious processes or patterns, Oberly applied the systematic categories: Attention, Cognition, and Apprehension, respectively.

In the present problem, the writer has adopted Oberly's method of procedure with but slight variation, believing it to be well adapted for application to the intensity-clearness problem. The necessary variation of stimulus-intensity was introduced by using three different brightnesses of dots (black, dark gray and light gray) on a white background; Oberly used only black on white. In an earlier experiment, Fernberger¹³ had obtained intensity-differences by using black dots on a white ground, and black dots on a medium-gray ground.

As stated above, the purpose of this experiment was to determine whether or not any constant relation exists between stimulus-intensity and degree of perceptual clearness. We assumed that such relationship would appear in a comparison of the values of the limens and the shapes of the curves of the psychometric functions for the different stimulus-intensities and under the different patterns of conscious process. Such objective evidence was amplified by frequent introspections from the Os, in the hope that information might be obtained in addition to that afforded by the individual judgments of the stimuli.

EXPERIMENTS

Apparatus. The apparatus used in this experiment for exposing the stimulus material was a Whipple disk tachistoscope.¹⁴ The adjustment of weights was regulated to give an exposure-period of 75 sigma, calibrated by the tuning-fork method. The pre- and post-exposure field was of uniform black, except for a white fixation mark at the center. The only illumination was supplied by a 25-watt lamp.

The stimuli consisted of 5 sets of white cards, 88 mm. sq.¹⁵ on which were pasted in haphazard order dots, 6.5 mm. in diam., and ranging from 2 to 12 in number. There were 33 cards in each set, 11 of which had *black* dots, 11 *dark gray* and 11 *light gray*, each brightness group ranging from 2

¹²H. S. Oberly, The range for visual attention, cognition and apprehension, this JOURNAL, 35, 1924, 332-352.

¹³Fernberger, *op. cit.*

¹⁴For a description of this apparatus see G. M. Whipple, *Manual of Mental and Physical Tests*, I, 1924, 264.

¹⁵Hurlock's 8-ply Oil Crest illustrating board was used.

to 12 dots. Thus there were in each set, 3 cards of each denomination: one black, one dark gray, and one light gray, all arranged in different haphazard orders. The arrangements were different for all five sets.¹⁶

These stimuli will be referred to as Bk, D, and L, respectively. The contrast of these three brightnesses on the white background of the cards thus afforded three intensities of stimulus.

Method of procedure. The tachistoscope was set up on a low table and the O seated so that his eyes were 2 m. from the exposure field, which at this distance, lay entirely in foveal vision. Instructions, read to the O at the beginning of each observation period, were as follows:

"You will be shown successively, for a very short exposure, cards which contain a varying number of dots on a white background. Immediately after the exposure you will report verbally:

"(1) The number of dots which you have apprehended.

"(2) The degree of assurance or certainty of your judgment, using this scale for your report: 5—if it is a 100-to-1 bet, 4—if it is a 5-to-1 bet, 3—if it is a 1-to-1 bet, 2—if it is a 1-5 bet, 1—if it is a 'guess' or 'do not know.'

"(3) The method of determining your report, whether by *Immediate judgment*, i.e. ungrouped, by *Grouping* of dots, or by *Counting*."

These instructions are the same as those used by Oberly,¹⁷ except for the omission of the word 'black' before 'dots' in the first sentence.

Accepting Oberly's results and conclusions as our starting-point, we defined the methods of determining reports as follows: *Immediate*—where all the dots "were perceived in a single flash of consciousness, with an equal and high degree of clearness." *Grouped*—where immediate perception occurred, as above, "but owing to different degrees of clearness, there was an attentional grouping of the stimulus dots." (Concerning this characterization we shall have more to say later.) *Counted*—where "some subsequent re-imagining of the stimulus material" provided the basis of the report.

In the Results we have presented, under the category of Attention, limens and coefficients of precision calculated from the correct judgments, based on the Immediate method. Under Cognition, we have included measures based on the Immediate method plus the Grouped method, i.e. those showing more than one level of clearness. Under Apprehension, we include measures based on all three methods: *Immediate*, *Grouped*, and *Counted*.

As soon as the O's gaze was directed toward the fixation-point of the pre-exposure field, the warning signal was given. This consisted of a 'Ready,' followed at an interval of approximately 1 sec. by a 'Now;' the catch was then released, which brought the exposure of the stimulus-card after the lapse of another second. Thus the actual stimulation followed the first signal at an interval of approximately 2 sec., allowing for maximal concentration of attention. The stimulus was exposed, as stated above, for a period of 75 sigma.

The O's 3-fold judgment was recorded as soon as given; then the next card in order was exposed as before, preceded by the signal. In order to obviate, as far as possible, unconscious memorization of individual cards or their sequence, the 5 sets of cards were shown in order from I to V, the cards being placed in a given position, which was called the 'A' position. At the completion of the 5 series (165 cards) in this position, the cards were

¹⁶The papers from which these dots were cut were obtained from Milton Bradley Co., and are listed by them as Black, Neutral Gray No. 1 (Light), and Neutral Gray No. 2 (Dark). Matched on a color-mixer, they were found to contain the following: Neutral Gray No. 1—black 63%, white 35%, yellow 2% (this was our 'light'); Neutral Gray No. 2—black 73%, white 25%, yellow 2% (this was our 'dark'); Black—black 100%.

¹⁷Oberly, *op. cit.*

turned to the left through an angle of 90° , and all 5 series gone through in this 'B' position; then, similarly with the 'C' and 'D' positions. In this way, a given card was shown in a certain position only after the exposure of 659 other stimuli. Another variation was provided by starting at different points in the sequence of the individual set.

The experimental periods were so arranged that no *O* ever observed more than three days in one week, nor longer than one hour at a sitting. A rest period of 10 or 15 min. was always allowed after each 20 or 30 min. observation period.

Each of the *O*s was given a period of preliminary training to familiarize him thoroughly with the procedure, so that the complex judgment had become perfectly mechanized before recording was begun.

The first series of observations was begun in February, 1925, and completed in June, 1925. The second series began in October and ended in December of the same year.

Each series consisted of 10 exposures of each of the 5 sets (of 33 cards each). Thus every value of stimulus from 2 to 12 dots, for each of the 3 intensities (Black, Dark Gray, and Light Gray) was exposed 50 times in each series, making a total of 3300 observations for each *O*.

Observations were made, for the most part, in a photographic dark-room. Toward the latter part of the second series we were compelled to transfer our apparatus to a large store-room of the department. Although a small amount of light entered from a distant window, careful scrutiny of the results gave no evidence of any change other than the normal improvement incident to practice, which had been apparent from the beginning.

Observers. The four *O*s, all members of the staff, were: Samuel W. Fernberger (F), Henry Sherman Oberly (H), Earl S. Rudisill (R), and Malcolm K. Macdonald (M). F and M were highly trained in giving introspective reports on psychophysical observations: H and R were less experienced in this sort of work. All had participated in the Training Series and were, therefore, thoroughly familiar with the apparatus and method of the experiment.

Handling of results. The judgments included, as stated above, quantitative estimates of subjective assurance, on a 5-point scale; following Oberly's procedure, the writer omitted from calculation all judgments given with an assurance less than '3,' i.e. an assurance so low that an *O* would not back it with at least an 'even-money' bet was assumed to be too much in the nature of a 'guess' to be significant. It is to be noted that F, M and H were aware of the omission of the '2' and '1' judgments in Oberly's experiment. F, however, was the only one who knew positively that a similar procedure was to be followed in this experiment. The suspicion that it might be so may conceivably have influenced H and M to give '3' judgments in some cases where the natural inclination would have suggested a '2.' Even if this were so, it seems highly improbable that any material difference would have resulted, inasmuch as all three intensities of stimulus would presumably have been affected equally. R had no knowledge of the omissions, being unacquainted with Oberly's paper.

The tables of observed relative frequencies were subjected to statistical treatment in accordance with the phi-gamma hypothesis. Limens (*S*) and coefficients of precision (*h*) were calculated for the two series separately. In this way a sort of check upon the results of the First Series was afforded by those of the Second Series, as to tendencies shown and effect of progressive practice.

RESULTS

In Tables I to IV will be found the percentages of observed relative frequencies of correct judgments made by each of the four *Os*. The top line gives the systematic categories, Attention, Cognition and Apprehension, which we have applied to the three conscious patterns or 'methods of determining' the reports. In the second line appear the three stimulus intensities, Black, Dark and Light (Bk, D, and L) under each of the process patterns. The third line contains the three degrees of subjective assurance; 5, 4, and 3 (2 and 1 having been discarded as explained above) under each of the intensities.

In the first column are the values of the individual stimuli (2-12). In succeeding columns are to be found the percentages of correct judgments given for each stimulus value, with each degree of assurance, for all intensities, under each conscious pattern. The upper half of each table shows results for Series I, the lower half those for Series II.

In Tables V, VI, VII, and VIII, are indicated the calculated results for all the *Os*. The first column contains the systematic categories, Attention, Cognition, and Apprehension, each coupled with the three degrees of subjective assurance. The first line in each of the groups indicates the calculated results of the observed relative frequencies of correct judgments given with an assurance of '5' (100-1 bet); the second line shows the calculated results of correct judgments given with assurance '5' *plus* those with assurance '4'; the third line shows the calculated results of observed correct judgments given with all three degrees of assurance ('5,' '4,' and '3') in summation.

These calculated results are arranged in 6 columns: the first 3 containing the limens (*S*) for the different intensity-degrees (Bk, D, and L); the second 3 containing the values of *h*, or coefficient of precision, under the various categories. To facilitate comparison of results for the two series, both have been grouped under their respective categories.

Analysis of Results. In the formulation of our problem, it was assumed that if perceptual clearness bears some constant relation to intensity of stimulation, such relation would be reflected in the size of the limens and the shapes of the psychometric curves. In selecting stimuli we accordingly chose those which seemed of sufficient intensity-difference to produce such variation in the size of *S* and *h*, if the relationship is found to exist.

Determination of significant difference in size of these measures required the setting up of a standard. It was arbitrarily decided to adopt a difference of 0.5 as our criterion of signifi-

TABLE IV
Observer M

Series	Stimuli No.	Category											
		Attention						Cognition					
		Bk			D			Bk			D		
		5	4	3	5	4	3	5	4	3	5	4	3
First	2	74	—	—	—	—	—	—	—	—	—	—	—
	3	98	—	—	82	—	—	22	—	—	18	—	—
	4	18	—	—	82	—	—	2	—	—	8	—	—
	5	—	—	—	—	—	—	80	—	—	90	—	—
	6	—	—	—	—	—	—	94	—	—	96	2	—
	7	—	—	—	—	—	—	94	2	2	86	4	—
	8	—	—	—	—	—	—	48	14	8	56	16	—
	9	—	—	—	—	—	—	26	22	12	16	32	—
	10	—	—	—	—	—	—	6	42	12	10	18	—
	11	—	—	—	—	—	—	—	16	22	—	4	—
	12	—	—	—	—	—	—	—	10	—	—	—	—
Second	2	52	—	—	—	—	—	48	—	—	44	—	—
	3	66	—	—	—	—	—	34	—	—	42	—	—
	4	4	—	—	—	—	—	96	—	—	100	—	—
	5	8	—	—	—	—	—	90	2	100	—	—	—
	6	—	—	—	—	—	—	100	—	—	92	—	—
	7	—	—	—	—	—	—	88	4	—	96	2	—
	8	—	—	—	—	—	—	82	10	2	78	10	—
	9	—	—	—	—	—	—	66	24	2	56	24	—
	10	—	—	—	—	—	—	14	26	10	12	24	—
	11	—	—	—	—	—	—	8	18	6	14	2	—
	12	—	—	—	—	—	—	—	6	14	—	—	—

cance for the limens and one of 0.2 for the precisions. Differences less than these we believed would be non-significant or, at best, of doubtful significance.

Turning to examination of the calculated results, Tables V to VIII, we find progressive increase in the size of the limens for all Os, from Attention to Cognition, to Apprehension. This was, of course, to be expected, inasmuch as the categories are progressively inclusive, as stated above. The improvement incident to progressive practice is evident by comparison of limens for Series II with those of Series I.

TABLE V
Observer F

Category	Series	Assurance	Limen			precision (h)		
			Bk	D	L	Bk	D	L
Attention	First	5	4.479	2.961	2.015	0.541	0.686	0.321
		5+4	4.479	2.961	1.975	0.541	0.686	0.293
		5+4+3	4.479	2.961	2.033	0.541	0.686	0.296
Attention	Second	5	4.496	2.600	2.833	0.324	0.367	0.436
		5+4	4.496	2.600	2.833	0.324	0.367	0.436
		5+4+3	4.463	2.600	2.833	0.335	0.367	0.436
Cognition	First	5	5.677	4.874	4.619	0.995	0.661	0.671
		5+4	5.784	4.930	4.785	1.092	0.667	0.695
		5+4+3	5.784	4.960	4.809	1.092	0.657	0.725
Cognition	Second	5	5.502	5.118	5.110	0.622	0.656	0.841
		5+4	5.502	5.200	5.143	0.622	0.628	0.967
		5+4+3	5.525	5.236	5.143	0.616	0.617	0.967
Apprehension	First	5	6.169	5.726	5.117	0.518	0.531	0.566
		5+4	6.673	6.597	6.089	0.447	0.567	0.537
		5+4+3	8.443	7.420	7.192	0.359	0.486	0.405
Apprehension	Second	5	6.396	5.661	5.650	0.588	0.561	0.592
		5+4	6.972	6.587	6.216	0.426	0.468	0.609
		5+4+3	8.956	7.937	7.871	0.341	0.378	0.442

For H and M improvement is most marked in Cognition and Apprehension, while in Attention there is a decrease, which is probably due to a tendency to characterize as *Grouped* some judgments originally given under the category of *Immediate*, rather than to an actual decrease of ability to grasp the stimuli immediately.

For F there is slight improvement Attention, especially for L stimuli, less for Bk and none for D. Under Cognition, F shows no improvement for Bk, slight for D and more marked for L. Under Apprehension, F shows uniform improvement (with one slight inversion), the greatest being again in L.

R shows marked and steady improvement throughout; he stated in one of his introspections, "there were more *Immediate* judgments to-day, for I seemed more capable of grasping an entire field. Re-imagining larger groups of dots was also easier."

Limens compared for the several Os. A comparison of the limens of Attention, Cognition, and Apprehension for the different stimuli and the different degrees of assurance reveals the following:

H, Table VI. The data show that in Series I, Attention, assurance 5, the order of the limens are L highest, Bk intermediate, D lowest; the differences, however, fall far below our criterion of significance; L being 0.029 greater than B., and 0.069 greater than D; Bk 0.04 greater than D. With assurance 5 + 4 and 5 + 4 + 3 the same order is maintained, the only variation being an increase of 0.018 for the L limen, a difference

TABLE VI
Observer H

Category	Series	Assurance	Limen			precision (h)		
			Bk	D	L	Bk	D	L
Attention	First	5	4.556	4.516	4.585	1.091	1.001	1.710
		5+4	4.556	4.516	4.603	1.091	1.001	1.623
		5+4+3	4.556	4.516	4.603	1.091	1.001	1.623
Attention	Second	5	4.338	4.240	4.468	0.966	1.048	0.870
		5+4	4.338	4.240	4.468	0.966	1.048	0.870
		5+4+3	4.338	4.240	4.468	0.966	1.048	0.870
Cognition	First	5	6.032	6.149	6.290	0.549	0.525	0.550
		5+4	6.140	6.353	6.825	0.414	0.505	0.485
		5+4+3	6.642	6.675	6.926	0.418	0.443	0.479
Cognition	Second	5	6.418	6.668	6.613	0.392	0.488	0.552
		5+4	6.552	6.796	6.714	0.384	0.506	0.535
		5+4+3	6.966	6.905	7.218	0.376	0.419	0.459
Apprehension	First	5	6.787	6.854	6.687	0.523	0.583	0.522
		5+4	7.255	7.173	7.005	0.424	0.543	0.488
		5+4+3	8.224	7.957	7.863	0.567	0.519	0.526
Apprehension	Second	5	7.626	7.463	7.379	0.381	0.450	0.454
		5+4	7.906	8.204	7.632	0.391	0.480	0.459
		5+4+3	9.118	8.802	8.832	0.379	0.577	0.573

which is still much below what we decided to consider significant. In Series II, Attention, similar relations are found as in Series I, only exaggerated; here the limens are the same for all three degrees of assurance, which indicates that judgments were given with assurance 5 only. L is 0.130 higher than Bk, and 0.228 higher than D; while Bk is 0.098 higher than D. No significance.

The results for Cognition, Series I, Assurance 5 show complete inversion, L being highest, D intermediate and Bk lowest; the differences being: L 0.141 greater than D, and 0.258 greater than Bk; D 0.117 greater than Bk. No significance.

With Assurance 5 + 4, similar though greater differences obtain; L is 0.472 greater than D and 0.685 greater than Bk. Here is our first occurrence of a significant difference, but it is reversed, *i.e.* the limen for the least intensive stimulus is higher than that for the most intensive!

With Assurance 5 + 4 + 3, the order is the same, viz. L, D, Bk; but the differences are non-significant, due to a greater relative increase in the size of Bk than for either D or L, and greater for D than for L. Under Cognition, Series II, Assurance 5 and 5 + 4, there is a shift in the order to D, L, Bk; with Assurance 5 + 4 + 3 another shift to L, Bk, D, but with no significance in any case.

Passing to the limens for Apprehension, Series I, Assurance 5, we find another shift to D, Bk, L, and again a change in the order for Assurance 5 + 4 and 5 + 4 + 3, to Bk, D, L; still without significant difference. In Series II, Assurance 5, the relative order remains the same, viz. Bk, D, L; not significantly different. With Assurance 5 + 4, a shift to D, Bk, L, occurs with differences as follows: D 0.0298 greater than Bk, D 0.572 greater than L, and Bk 0.278 greater than L. Here is a significant difference as between D and L, the first and only time for this *O* when a more intense stimulus produced a significantly higher limen than that for the less intense!

TABLE VII

Observer R

Category	Series	Assurance	Limen			precision (h)		
			Bk	D	L	Bk	D	L
Attention	First	5	2.576	2.966	2.917	0.418	0.611	0.509
		5+4	2.576	2.966	2.917	0.418	0.611	0.509
		5+4+3	2.576	2.966	2.917	0.418	0.611	0.509
	Second	5	4.352	4.148	4.030	0.719	0.576	0.906
		5+4	4.352	4.148	4.030	0.719	0.576	0.906
		5+4+3	4.352	4.148	4.030	0.719	0.576	0.906
Cognition	First	5	5.157	5.000	4.999	0.639	0.474	0.376
		5+4	5.358	5.269	5.160	0.638	0.457	0.425
		5+4+3	5.358	5.269	5.190	0.638	0.457	0.355
	Second	5	5.592	5.613	5.790	0.832	0.696	0.636
		5+4	5.610	5.705	5.808	0.814	0.673	0.656
		5+4+3	5.622	5.705	5.866	0.812	0.673	0.642
Apprehension	First	5	5.431	5.540	5.358	0.699	0.640	0.543
		5+4	6.210	6.455	6.378	0.353	0.529	0.413
		5+4+3	6.399	6.799	6.595	0.304	0.452	0.339
	Second	5	5.927	6.196	6.074	0.741	0.679	0.703
		5+4	6.634	6.815	6.585	0.461	0.522	0.545
		5+4+3	6.999	7.050	6.901	0.330	0.423	0.346

It is to be noted, at this point, that from a quantitative point of view there is less intensity-difference between the two grays than between the dark gray and the black stimulus, as is shown by the relative percentages of black noted under *Apparatus*. With Assurance 5 + 4 + 3, the order again changes to Bk, L, D, the differences being non-significant.

Summing up the results for Observer H, we find that there are but two cases where a significant difference is shown between limens for different intensities of stimulus under the same process and with the same degree of assurance. In Series I, Cognition, Assurance 5 + 4, the L limen was 0.685

higher than the Bk. In Series II, Apprehension, Assurance 5 + 4, D gave a limen 0.572 higher than did L. In 10 cases L was highest; Bk and D were highest in 4 cases each.

R, Table VII. Without going into so minute detail in examination of R's limens, we may summarize the results as follows:

The relative order under Attention, Series I, all assurances, (judgments under this category being given with assurance 5 only) is: D, L, Bk. For Series II, it is Bk, D, L, with non-significant differences. Under Cognition, Series I, all assurances, the order is Bk, D, L; Series II, all assurances, L, D, Bk. Under Apprehension, both series, all assurances, the D limens are high in every case; intermediate values are given for Bk in 3 cases and for L in 3 cases.

In no case was there a significant difference for R. In 9 cases D was highest, in 6 cases Bk, and in 3 cases L.

TABLE VIII
Observer M

Category	Series	Assurance	Limen			precision (h)		
			Bk	D	L	Bk	D	L
Attention	First	5	3.124	3.277	3.211	0.542	1.113	0.766
		5+4	3.124	3.277	3.211	0.542	1.113	0.766
		5+4+3	3.124	3.277	3.211	0.542	1.113	0.766
Attention	Second	5	2.607	2.863	2.710	0.411	0.739	0.390
		5+4	2.607	2.863	2.710	0.411	0.739	0.390
		5+4+3	2.607	2.863	2.710	0.411	0.739	0.390
Cognition	First	5	6.848	7.148	7.081	0.373	0.396	0.496
		5+4	8.038	7.619	7.716	0.254	0.395	0.417
		5+4+3	8.737	7.960	8.308	0.253	0.361	0.361
Cognition	Second	5	8.062	7.672	7.899	0.529	0.599	0.615
		5+4	8.903	8.493	8.708	0.475	0.491	0.499
		5+4+3	9.275	8.994	9.164	0.417	0.392	0.456
Apprehension	First	5	7.277	7.228	7.138	0.446	0.481	0.627
		5+4	8.489	7.804	7.948	0.338	0.475	0.489
		5+4+3	9.237	8.207	8.534	0.304	0.409	0.407
Apprehension	Second	5	8.134	7.714	7.951	0.553	0.642	0.625
		5+4	9.355	8.770	8.966	0.481	0.456	0.457
		5+4+3	9.908	9.579	9.636	0.435	0.329	0.413

M, Table VIII. M's results show the following features: In Attention, both series, all assurances, the D limens are the highest, the intermediate values going to L. The differences are all small, however, the greatest being that between D and Bk, Series II, D being 0.256 higher than Bk. In Cognition, we find the order Bk, L, D in every case but one, where it is D, L, Bk (Assurance 5, Series I); with Assurance 5 + 4 + 3, Series I, occurs the first significant difference: Bk 0.777 greater than D, but L 0.348 greater than D.

In Apprehension, both series, all assurances, the order is the same as for Cognition, viz. Bk, L, D, in every case but one, where it is Bk, D, L (Assurance 5, Series I).

In 5 cases we find significant differences, always in favor of the Bk: 3 times against D, and twice against L.

Thus we find M showing a significant difference 6 times: none under Attention, once under Cognition, 5 times under Apprehension, and always in favor of Bk.

Considering absolute differences, we find: Bk highest 11 times, D highest 7 times, L highest no times, Bk intermediate no times, D 1 time, L 17 times, Bk lowest 7 times, D 10 times, L once.

F, Table V. In F's results we find a striking contrast to those of the other Os. In every case the Bk limens are the highest; in 15 cases the D limens are greater than the L, but in only 3 cases are the limens higher than D. Significant differences are shown between Bk and L, in every case except Cognition, Series II, all assurances; Bk, is significantly higher than D in every case in Attention, both series; in every case in Cognition, Series I. In 3 cases under Apprehension, D is significantly higher than L; also in Attention, Series I, all assurances; and in Apprehension, Series I, Assurances 5 and 5 + 4. Bk highest 18 times, D no times, L no times; D higher than L 15 times; L higher than D 3 times.

Introspections. Additional evidence of the inconstancy of effect of intensity-differences upon the size of the limens is afforded by some spontaneous introspective reports of the Os.

F, who, it will be remembered, knew in advance of the intensity-differences, stated at the close of the first observation period that "in not over 6 of the cards was he conscious of any differences in brightness of the dots."

H reported after his first observation period, "there are, I believe, several kinds of cards with dots of black and gray. On not more than three cards was I conscious of the difference. One card seemed to 'blare,' because of the great number of black dots." Three weeks later he reported, "Eight cards definitely gray, three definitely black." And, again, one week later, "I noticed that there were cards with black dots that were almost impossible for me. They seemed to be too bright, while the gray dots were not nearly so hard to attempt. I do not think that there were more than 10 cards exposed today in which I was conscious of the difference in color of the dots." Two months later, he said: "A very few times I was conscious of difference of brightness; some cards with black dots were very vivid."

R gave, at the very last, in the course of a detailed introspection on every card of a whole series, the following varied reports for the different intensities:

Bk stimuli. "They stood out boldly" [the number apprehended was incorrect]. "Clear at first, but I couldn't grasp any on presentation (of report)" [Number wrong]. "Clear—re-imaged," [Number wrong].

D stimuli. "The dots seemed very bright—the clearness was quite pronounced" [Number wrong]. "Very clear" [Number correct]. "Not so clear, but certain at once" [Number correct]. "Fairly clear—no uncertainty" [Number correct].

L stimuli. "The whole thing faint" [Number correct]. "Not very clear" [Number wrong]. "Not so clear—absolute certainty—came at once—no re-imaging required—dots seemed large but not saturated" [Number correct].

The introspections of R are strongly confirmatory of Dallenbach's finding relative to the independent variability of attributive and cognitive clearness. With attributive clearness high or low may be combined either high or low cognitive clearness.¹⁸

¹⁸Dallenbach, *Attributive vs. cognitive clearness, loc. cit.*

The introspective reports, quoted above, of F, H, and R, and others less specific of M, all indicate clearly the extreme variability of the intensity effect.

Size of h compared for the several Os. Observation of the size of the coefficients of precision (h), for the 3 categories for the several Os, shows the following features.

For H, the values of h are highest for Attention, for all intensities and all degrees of assurance; there is about equal division of intermediate values between Cognition and Apprehension, with no definite trend toward any one intensity.

For F, the h -values are highest for Cognition with Bk and L; for Cognition and Attention with D.

For R, Cognition shows the higher h -values for Bk and D, in Series II; and for Bk in Series I, whereas Attention gives the higher values of h for L in Series II, and for D and L in Series I.

For M, Attention gives higher values for h for Bk, D, and L in Series I, and for D, in Series II. Apprehension gives higher values for Bk and L in Series II.

The significant differences—the criterion of 0.2, it will be remembered, was fixed upon as suitable—are, in the main, as indicated above. In several cases, in addition to the foregoing, significant differences are shown between the value of h for assurances 5 and $5 + 4 + 3$, but without altering the ratios.

No constant trend whatever appears in these h values, in relation to either differences of intensity or conscious process. These results confirm Fernberger's findings in his study of the range of visual apprehension in which he states, "it was expected that the form of the curves might vary for the different series, thus showing the influence of the brightness of the backgrounds" [he used black dots on a white and on a medium gray background] . . . but "no such variation is present for any subject."¹⁹

DISCUSSION

Table IX summarizes the relative frequencies with which the possible orders of precedence as to size of limens occurred for the several Os. For instance, the number of times that the limens occurred in the order, Bk highest, D intermediate, L lowest was for F, 15 times; for H, 3 times; for R, 6 times; for M, once. At the other extreme, the order L high, D middle, Bk low, occurred only 6 times: 3 times each for H and for R.

By using different combinations, we may arrive at determinations of various relative frequencies of occurrence. For example, we find by combining the figures lying in the first and second rows, in any vertical column, the number of times the Bk stimulus gave the highest limen, *e.g.* for F, 18 times; for H

¹⁹Fernberger, *op. cit.*, 129.

4 times; etc. Similarly, the number of times L produced a higher limen than Bk, for all Os, may be found by adding the totals of rows 4, 5, and 6.

From Table IX it will be seen that for F, Bk was by far the most effective stimulus, giving the limens higher than both the grays in every case; D was next in order of effectiveness, in that its limens exceeded those of L in 15 out of 18 times.

TABLE IX
RELATIVE FREQUENCIES OF DIFFERENT ORDERS OF LIMENS

Order of Limens	O				Totals
	F	H	R	M	
Bk—D—L	15	3	6	1	25
Bk—L—D	3	1	0	10	14
D—Bk—L	0	2	3	0	5
D—L—Bk	0	2	6	7	15
L—Bk—D	0	7	0	0	7
L—D—Bk	0	3	3	0	6

For M, too, Bk was the most effective, as shown by its frequency of predominance: the Bk limen was higher than both D and L, 11 times. On the other hand, L limens exceeded Bk 7 times, and D 10 times, indicating intermediate effectiveness of L, instead of D, as shown in F's results.

For R, D appears the most effective of the 3 intensities, exceeding Bk 12 times, and L 15 times. Bk is next most effective, and L least.

For H, L shows higher than Bk 12 times, and higher than D 11 times. Bk comes next with 11 limens higher than the D, and 6 higher than L.

From the foregoing it appears that intensity does not exercise a constant effect upon the size of the limens. For F, the order of effectiveness is Bk, D, L; for H: L, Bk, D; for R: D, Bk, L; and for M: Bk, L, D.

TABLE X
RELATION OF THE LIMENS

Category	Relation	O				Relation	O			
		F	H	R	M		F	H	R	M
Attention	L — Bk	0	6	3	6	Bk — L	6	0	3	0
	D — Bk	0	0	3	6	Bk — D	6	6	3	0
	L — D	3	6	0	0	D — L	3	0	6	6
Cognition	L — Bk	0	6	3	1	Bk — L	6	0	3	5
	D — Bk	0	5	3	1	Bk — D	6	1	3	5
	L — D	0	3	3	5	D — L	6	3	3	1
Apprehension	L — Bk	0	0	3	0	Bk — L	6	6	3	6
	D — Bk	0	2	6	0	Bk — D	6	4	0	6
	L — D	0	2	0	5	D — L	6	4	6	1

Referring to Table X, we find the relative frequencies of predominance arranged under the systematic categories or conscious processes.

In the first 4 columns appear the number of times, for each O, that a less intense stimulus gave a higher limen than did a

more intense, while in the second 4 columns the reverse is shown. Each group is fractionated into the 3 systematic categories or conscious processes, under which the frequencies occurred.

For F, only under the category of Attention, there appeared a predominance for a less intense stimulus: L was greater than D 3 times. In every other case the more intense stimulus always gave higher limens.

For H, a predominance of L is shown, over both Bk and D, every time under Attention, and a similar predominance of Bk over D. Under Cognition, the same relation holds for L as compared with Bk; D, however, takes the lead over Bk in 5 cases out of 6; while the L predominance over D drops to 50% (3 out of 6). Passing to Apprehension, we find the superiority definitely shifted to the more intense stimuli: L going below Bk every time; D below Bk 4 out of 6 times, and L below D 4 times.

For R, the predominant effectiveness of D as conditioning higher limens is definitely shown in passing from Attention to Apprehension.

For M, the tendencies noted earlier are here confirmed under Cognition and Apprehension, viz. Bk greater than D, Bk greater than L, and L greater than D.

From these data it seems safe to generalize the relations as follows: In general under the conditions of this experiment, objective intensity of stimulation is most effective in conditioning perceptual clearness under the process of Apprehension, less so under Cognition, and least under Attention.

Let us now scrutinize more closely the conscious processes here involved, in an attempt to get some further light on the differences shown above.

It is obvious that in passing from Attention, to Cognition, to Apprehension, we are traversing an ascending scale of mental complexity. Attention is the simplest process; in it the stimulus material comes to consciousness in a single flash of awareness, with an equal and high degree of clarity. In regard to this category, the introspective reports of the Os agree.

R reported: "When I characterized a judgment as *Immediate*, it was immediate, no intervening process—all happened in an instant and I was certain at once." Again: "Equal clarity—all in an instant—no re-imaging—absolute certainty and all came at once—no verification was needed."

H reported: "The *Immediate* judgments are based on the grasping of the dots without any conscious grouping or counting." "*Immediate* reports were clear—no question in my mind, and no subsequent process was involved."

"*Immediate* reports were given when all dots were clear—a focus which left no doubt in my mind."

M reported: "By *Immediate* I mean that all dots are clear and are perceived immediately upon the fall of the shutter."

It seems evident that this category is correctly described. In Cognition, which we defined tentatively as one in which "immediate perception occurred, but owing to different degrees of clearness, there is an attentional grouping of the stimulus dots," all Os agree as to the process of becoming aware of groups of dots.

H states: "In *Grouping* there is a definite grouping of the dots, generally accomplished by taking in twos, threes, or fours."

R says: "When I answer *Grouped*, several dots 'stick together' forming a unit, while another or several other units are formed at other locations."

M reports: "The dots seem more or less naturally to fall into groups. If there is merely one of these groups I report an *Immediate* judgment; if two or more groups I report *Grouping*."

So far as the grouping is concerned, there is no question, but when the factor of immediacy of the *Grouped* judgments is scrutinized, serious doubts arise.

R reported: "The *Grouped* judgments are almost immediate, with some one group particularly clear, the others less clear, but all somehow belonging together." "Got 3 groups of 2 each—it seemed the middle 2 first, then 2 above and then 2 below—no re-imaging—but there seemed to be temporal succession" (this report was in response to a card with 6 L dots). "Three and three, got those to right slightly ahead of those to left" (this on another 6-stimulus card, D dots).

H reported: *Grouped* judgments as based on a reading of the after-image, i.e. the *Anhang* or perseverative image, subsequent to actual stimulation.

M reported: *Grouped* judgments as based on a 'successive' awareness of the dots, e.g. a '2' judgment was "one dot, then another;" '3' was "two and one —succession."

These introspective reports from three of the *Os* definitely indicate a temporal sequence as characterizing this process, yet without the mediation of re-imaging. The actual retinal stimulation gives rise to an immediate awareness in which all the dots are of equal and high degree of clearness; the judgment based on this momentary flash of consciousness is what we have called Attention. The conscious effect of stimulation is not, however, confined to this momentary flash, but continues for a more or less durative period as the perseverative image. It seems that the *Grouped* judgment (Cognition) is arrived at by a reading of this image, by 'successive attentions'²⁰ to smaller groups, and a rapid totaling of these part-judgments.

The *Counted* judgments, or Apprehension as we have called this process, seem definitely to be characterized by a re-imaging or calling back into consciousness of a process which has, wholly or in part 'faded out.' Frequently, if not always, some group or groups remain in consciousness, as part of the perseverative image which has not 'faded;' this forms the nucleus which is later amplified by the re-imaged dots.

H said: "With *counting* I use any method, mixing up *grouping* and *counting*. I generally have an immediate flash of the dots at the point of fixation and begin to group or count from that point."

R states: "With large numbers in *counted* judgments, I usually get a part of the field immediately, usually the upper left."²¹

²⁰Pillsbury, *Attention*, 1908, 67.

²¹It is interesting to note that the three *Os* who mentioned the direction in which the image was read were all different in this respect: R read the dots from left to right; M from top to bottom; and H from bottom upward.

Thus, it appears, as Oberly observed in his paper,²² that progressive elaboration of mental process occurs as the complexity of the stimulus material increases, *i.e.* as the number of dots is increased.

Reference to Tables I to IV shows the relative frequencies of individual judgments for the several *O*s in respect to this elaboration of process.

F, Table I. *F* shows a gradual shift from Attention to Cognition. The great majority of his Bk 2-, 3-, and 4-dot cards, and most of the D 2- and 3-dot cards were grasped under the process of Attention; the L stimuli being for him less effective, required an earlier shift to Cognition. The shift from Cognition to Apprehension, occurs rather suddenly at the 5-dot cards for D and L, and at the 6-dot cards for Bk. *F* depended upon the more complex process of Apprehension for the grasping of everything above 6, with the exception of four Bk 7-dot cards.

H, Table II. With H the shift from Attention to Cognition occurs rather suddenly at 5, and that from Cognition to Apprehension at 6 and 7. This *O* shows an almost equal distribution of Cognition and Apprehension judgments.

R, Table III. With R, the break from Attention to Cognition occurs at 3, and a rather high percentage of 6 come under Apprehension. The 2nd Series shows the great improvement made by this *O* as a result of progressive practice.

M, Table IV. M's results show an almost complete dependence upon Cognition. It seems a rather significant fact that this *O* was of strongly visual concrete imaginal type. This fits in well with Hyman's findings that length of span was correlated with relative duration of visual after-image.²³ This *O* showed the highest limens of all the *O*s for both Cognition and Apprehension. Inspection of his results for Series II shows also the very high assurance with which his judgments were given: only 8 had assurance less than 5 up to and including the 6-stimuli.

Thus it would seem that for the lower values of stimulus, the univocal process of Attention is adequate, and the awareness comes immediately and with maximal clearness. With the intermediate stimulus-values a more complex conscious process is required, which takes, sometimes at any rate, a certain length of time for exploration of the after-image. With the higher values, the organism is pushed to its utmost to grasp the material presented, and has recourse to whatever additional means are at its disposal, *viz.* a re-imagining of the material. If this analysis is correct, the reason is plain why intensity differences fail to become operative in the majority of cases until the more complex processes are brought into play. The experimental setting and the process of training bring about the establishment of a mental 'set' that is of varying efficacy for the different *O*s.

²²Oberly, *op. cit.*

²³J. P. Hyman, The distribution of attention, *Psychol. Rev.*, 10, 1903, 373-403, 498-533.

For instance, with H, the experimental conditions were such that it was not until the higher stimulus values were presented that he was forced to avail himself of every factor in the situation that could serve to bring the awareness for which he was striving. Under the process of Apprehension, with its expedient of re-imaging added to the operations used in Attention and Cognition, the factor of intensity at length became operative and gave the correspondingly higher limens for Bk and negligible differences between the D and L, due to too slight intensity differences.

With F, greater experience in introspective work along the lines of psychophysical observation enabled him to avail himself of the intensity-differences at an earlier stage.

R's predominance of D over Bk, and the equality of intensity effect as between Bk and L in Apprehension, offer an anomalous situation, as do also, though in less degree, M's higher limens for L than for D.

Pending further illumination on this perplexing question, we may be justified in formulating, in a tentative way, the conclusion that:

Intensity differences are of variable effectiveness in conditioning clearness of perception, the latter being presumably reflected in the size of the limens as shown in this experiment.

SUMMARY

(1) Liminal differences are shown for all three values of stimulus-intensity.

(2) Stimulus intensities do not, however, seem to have any constant effect for any of the Os.

(3) The stimuli effective in conditioning highest limens are: for F, Black definitely the most effective; for M, Black most effective, with Light predominant over Dark; for R, Dark; for H, Light.

(4) In general, a predominant effectiveness is found for the more intense stimuli under the category of Apprehension, less so under Cognition, and least under Attention.

(5) Confirming Fernberger's findings, no constant variation is shown by the values of the coefficients of precision as reflecting the influence of variations of stimulus-intensity.

